

COUNTRY ROADS.¹

THEIR RELATIONS TO OTHER LINES OF COMMUNICATION AND TO THE STATE. HOW TO MAKE AND MAINTAIN THEM.

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GENERAL REMARKS.

Although volumes have been written on this subject, and everyone is presumed to know more or less about it, the present condition of the roads of this country is such as to warrant continuous agitation, until the people, who alone possess the power to apply the remedy, shall realize that their own interests will be best served by enforcing a radical improvement in their condition.

It is safe to say that of all the various systems of inter-communication by land or water, there is none more important, more wasteful, more expensive or more susceptible of improvement than our public highways, and yet this enormous waste, which is a real tax upon all classes of citizens, has been allowed to exist mainly through ignorance, but partially, also, from the fear that the lighter tax necessary to effect its removal may not be intelligently applied. It can hardly be otherwise under our existing laws and modes of administration.

Another strong reason for its existence is found in the fact that the individual is impotent to effect a change of so great magnitude, and that concerted action of masses of citizens is difficult to obtain in public matters. But an intelligent constituency is awakening to the importance of removing this false economy and *laissez faire* policy, and by united appeals to our legislators, substituting an active and energetic reform.

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THE ECONOMIC PROBLEM.

Engineering is nothing if not economic. In the location and construction of ways of communication it is to find the line of least resistance and of least cost, both to build and maintain, but especially the latter.

The relative measures of the numerous resistances to be overcome may well be summed up, practically, by the cost of moving any unit of load, say one ton, over a unit of distance, say one mile, known as the "ton-mile." A comparison of these costs or tariffs will reveal some interesting if not surprising results as to the value of the resistances to traffic by common roads, railroads, canals, rivers or lakes, and on the broad ocean. To exhibit them more fully they are arranged in tabular form and are also plotted graphically to scale. The rates taken are from current schedules for freights in bulk with a first-class equipment. They are as follows:

Table Showing the Relative Economy of Movement of Freight Based upon the Cost per Ton, per Mile, by Various Systems.

THE WAY.	Cost in Mills.	Relative Rates.	Relative Distances.	Relative Areas.
By Wagon.....	150	.200	1	1
By Railroad.....	5	6.6	30	900
By Canal.....	3	4	50	2,500
By River or Lake.....	2.5	3.3	60	3,600
By Ocean.....	.75	1	200	40,000

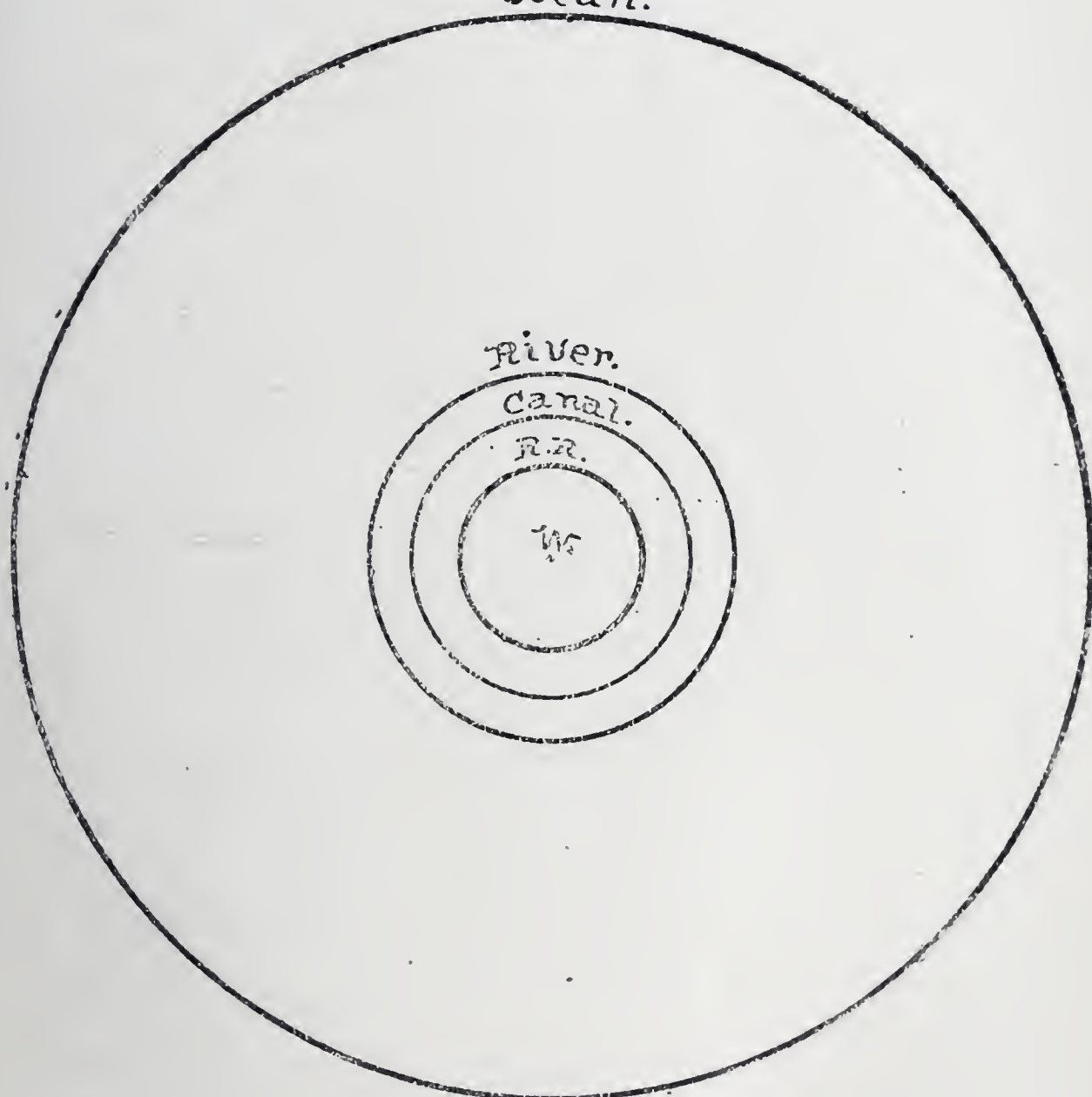
Taking the ocean rate as a unit of comparison, it is seen that the cost of movement by rail is 6.6, while by wagon it is 200 times as great (column 3). If, however, the wagon ratio be assumed as the unit, then it will appear from column 4 that the ton may be carried 30 miles by rail to one by common road, or 50 by canal, etc., and if the point of distribution were in the center of a circle having equal facilities in all directions, the relative tributary areas would be given in the fifth column. These results are, perhaps, made more impressive by the accompanying diagram, in which the wagon area is the small dot or point in the center, whose radius is taken at one unit. The others are plotted from column four.

It will be seen from the third column that at these rates the cost of movement by wagon is 200 times that by large ships, and about 30 times that by freight cars. In short, before the farmer

can avail himself of any of these cheaper lines of travel for his produce he must pay a heavy tax in overcoming the great resistances between the barn and the station. The trouble does not lie with the railroads, which are forced to use every effort to reduce the cost in order to restrain the traffic. It is with the road, and it requires no second thought to see that these two systems are intimately

Fig. 1.

Ocean.



Limits.

connected and mutually dependent. If the roads were in such good condition as to be available at all seasons, there would not be so great variations in rates, and less danger of an excess of freights at one time with a deficiency at another. The rolling stock could be employed to better advantage and the freight be handled more cheaply, while the farmer could take advantage of better prices and avoid a glut on the market.

These are but a few of the incidental benefits resulting from improved roads as feeders to railroads, and they serve to show that it is to the interest of the latter companies as well as of the farmer to improve the roads. They would then become most important "feeders," serving to stimulate population, production, and wealth with its consequent traffic.

RELATION TO THE STATE.

These figures have also a direct bearing upon the politico-economic problem as it affects the prosperity of the state or nation.

It will be seen that the railroad rates render 900 acres available as food sources to our busy manufacturing centers as compared with one acre at the wagon rate of tariff. Canals, if built of proper size and well maintained and operated, would still further increase this theoretic area nearly threefold more, or 2,500 times.¹ Hence the great value of waterways and the inestimable benefits conferred by the Erie Canal, not only on New York City and State, but on the nation. Suppose, however, the rate by wagon could be reduced by the improvement of the roads, to say five cents per "ton mile," what would the result be? It would put in motion a large tonnage of the baser sort that cannot now be handled at any price; it would give a large margin for profit on many products which are now moved at a loss, and would directly benefit both the producer and consumer. In 1887, the railways of the United States carried over 557,000,000 tons of freight. Most, if not all of this, had to be handled at one or both of the terminals in wagons. If the average distance hauled was but one mile, and the saving in the cost of the movement were ten cents, the annual economy would amount to \$55,200,000. That the cost of hauling may be very greatly reduced will be seen when we come to consider the resistance offered by grades, surface, and distance, all of which are involved in the engineering problem.

Since roads are, or should be, public highways, it is evident that so far as practicable they should be under intelligent public supervision and be regulated by a systematic management vested in local officers under State laws. The trunk lines, of which few are now required, should be more immediately under the control of

¹ See also a paper by the author on *Canals and Their Economic Relations to Transportation*, published by the American Economic Association, Johns Hopkins University, Baltimore, Md.

the State. The main lines, connecting populous centers and not forming links in a trunk line, under county supervision, and the local roads under township control. The cost of construction and maintenance should, by no means, be limited to rural districts; but all parties interested and benefited should be required to contribute their quota to this road fund. As has been shown, this includes the railroads, and the cities for improved roads would soon result in lowering the price of raw material for the benefit of manufacturers and others.

The present method of requiring the township to maintain the roads within its borders in some instances works an injustice. For example, it sometimes happens that a road skirts a river on one side, and is cut off from use to the people of its township on the other by steep and high mountains, so that the residents cannot reach it, yet they must maintain it for the benefit of others without compensation. Again, many counties are required to maintain miles of roads which are not only of no benefit but an absolute obstruction to travel due to their very defective location, some being too straight, others too crooked. By being too straight, is meant those roads which do not turn aside for hills or valleys, but require the load to be dragged up and down at great loss of power and time. If on such a road but half an ordinary load may be hauled, it would evidently require two trips to convey the load from end to end, and the effect is the same as if the road were of double the length. The same objections apply to the road which is too crooked, requiring an excessive cost for maintenance and a waste of land which could be rendered productive by cultivation, instead of being a tax. These few considerations it is hoped will be sufficient to show that the problem is not the simple one of digging two ditches and throwing the earth into the berm between them, which anyone may do, but one requiring a careful adjustment of the grades and lines to the topography in such a manner as to give the least resistance and the shortest line for the least money. It is in short

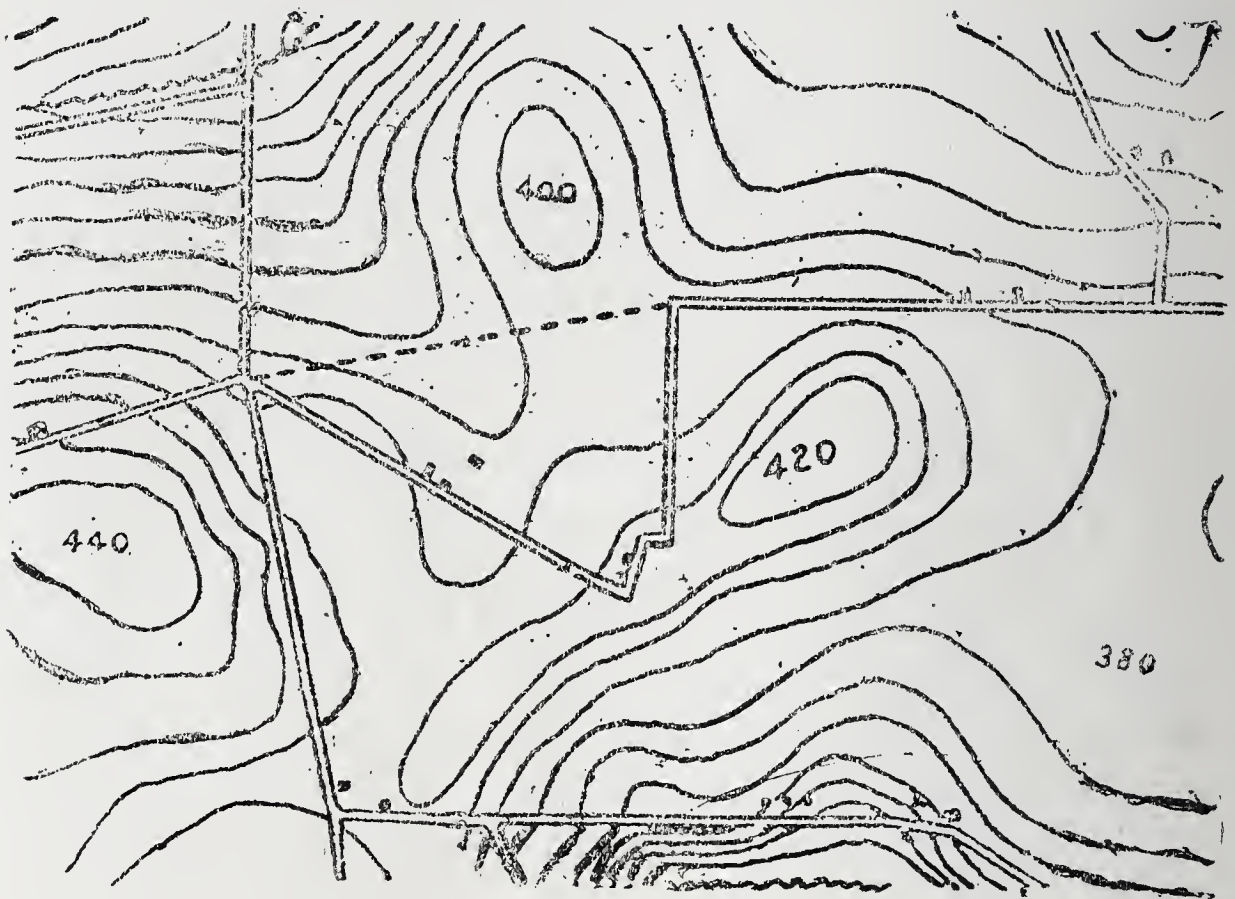
A COMPLICATED ENGINEERING PROBLEM

which should be thoughtfully considered before many of the very objectionable obstructions now existing are permanently fixed by a metalled road. This can best be done, and should by all means be provided for in the proposed revision of the law by requiring a thorough survey and re-adjustment of the location of the road in

each township, not only with reference to topography, drainage, local and personal requirements, but also with reference to their relation to the general system of county and State roads by a competent engineering commission.

A few instances may serve better to show the great importance and utility of such revision. Fig. 2 illustrates a location

Fig. 2.



Revised line - - - - -

where a straight line, as dotted, would give better grades and at the same time would save the eighty per cent. excess of distance over the bee line, thus rendering that much more land available for farming.

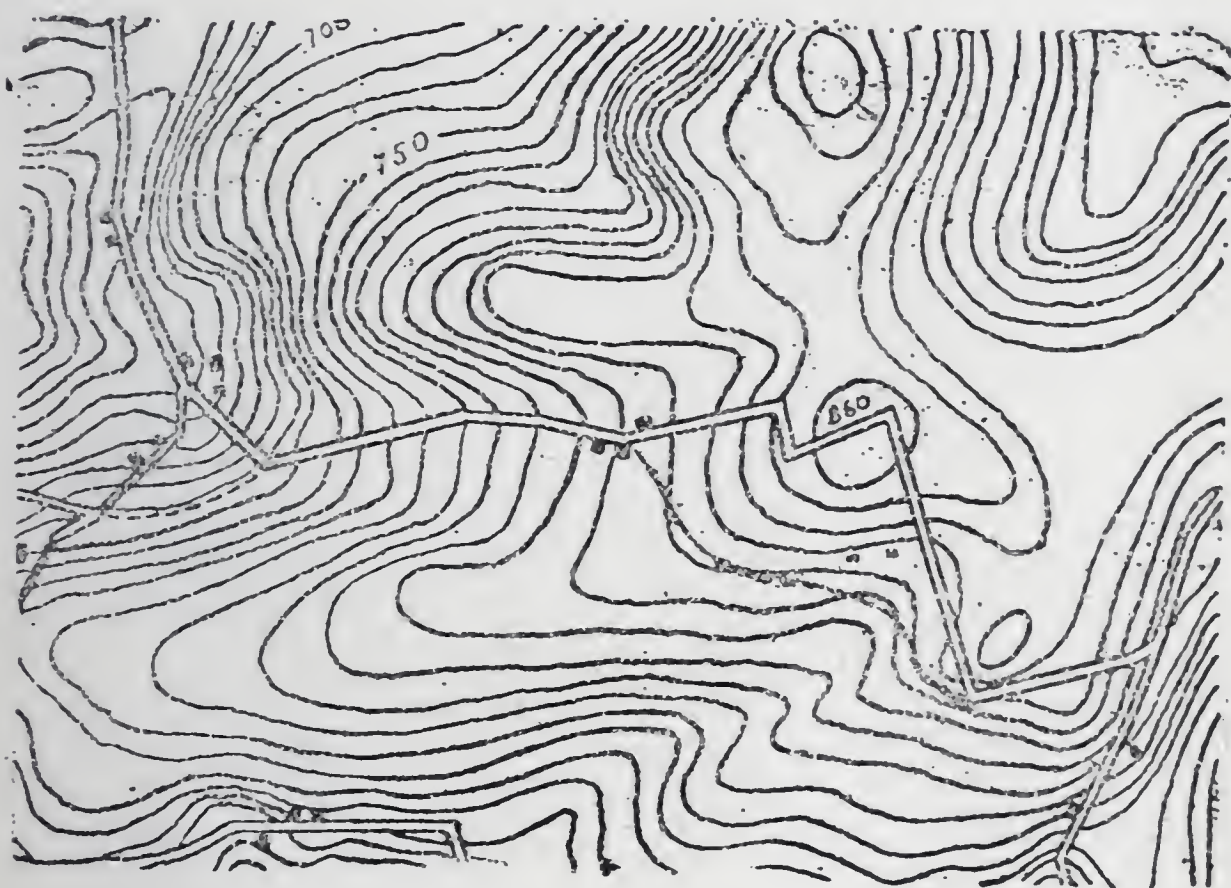
Fig. 3 is a case where the road is made longer than it need to have been, apparently only to obtain a view from the top of the hill, instead of following the slopes at a much easier grade and less distance. It also shows how a level line of a few hundred feet would save ascending and descending a hill fifty feet high.

Fig. 4 is a similar case of going out of the way to ascend a hill only to descend again without compensation.

These are but few of very many instances where a much better location can be obtained for less money than upon the old line.

It is firmly believed that the mere saving in cost of construction would more than pay for the cost of surveys and revision. Were the entire State so carefully projected as is the South Mountain District on the topographical maps of the Second Geological Survey, it would be a comparatively inexpensive and simple matter to make the revision, for the topography must furnish the key to the solution. In the above figures the level or "contour" lines represent elevations ten feet apart, and the horizontal scale is 400 feet to one inch.

Fig. 3.



Revised line - - - - -

The entire problem may be conveniently divided into these several parts.

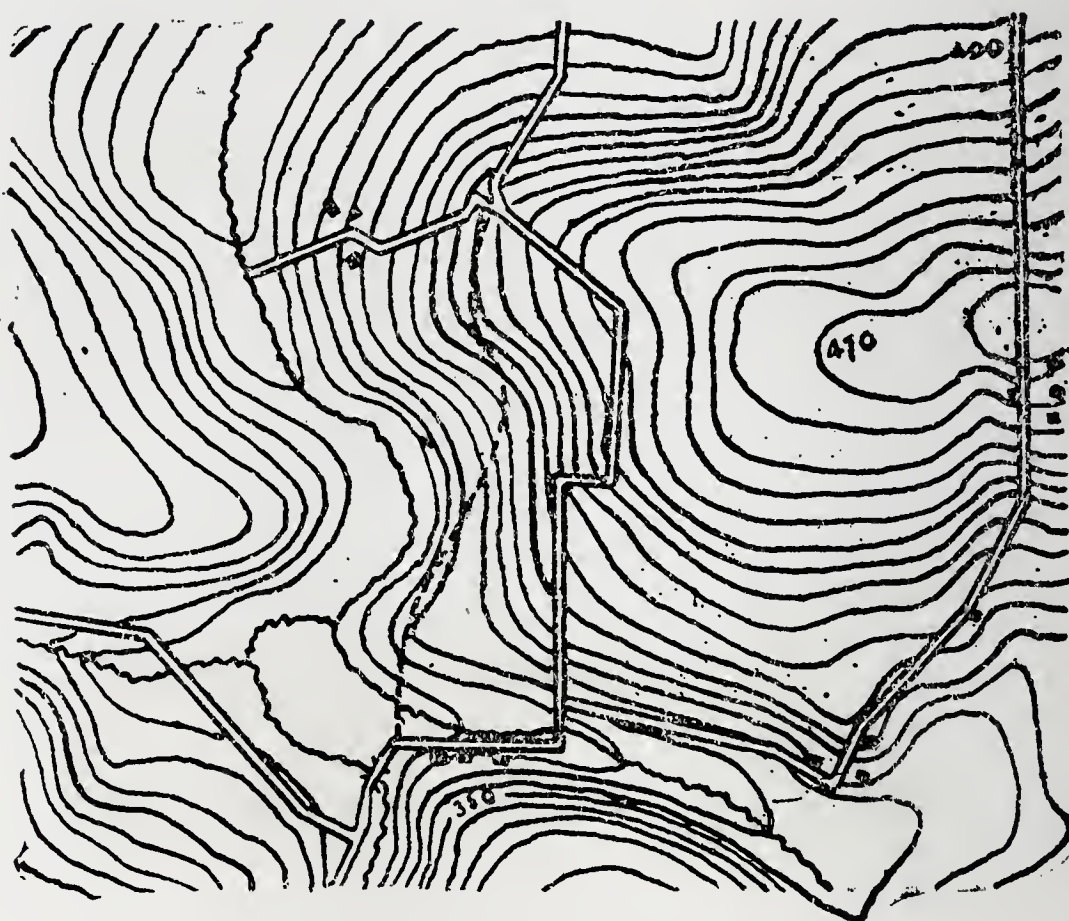
1. The *location*, involving a knowledge of the principles of mathematics as applied to the adjustment of the line to the topography in such a manner as to require the least work in construction, consistent with the shortest distance, best grades, suitable material and requirements of traffic with the least damage to property.

2. The *construction* requiring a careful consideration of the relation of the load to the resistance offered by various soils under

different conditions; the physical properties of the materials available; their proper sizes, forms, distribution, and adaptation to the purpose, and, above all, special attention to a thorough system of drainage for both surface and sub-soil waters.

3. The *operation* comprising the relation of the power to the resistances, as measured by the cost of movement over various kinds of surfaces; the hardness and smoothness of the wearing surface; the mechanical resistances; the grades and other requirements.

Fig. 4.



Revised line - - - - -

4. The *maintenance* as affected by traffic, character, and cost of material, methods of preparing and applying same, character of supervision, etc.

These constitute the scientific, physical, and mechanical features of the problem. On the other hand, and quite as important, there are the legal, legislative, financial, and social elements.

Intricate as the question is, it can hardly be more complicated in Pennsylvania than it was about a century ago in England where the results, as seen to-day, are evidence that it is capable of a satisfactory solution.

Hence, much may be learned from the experience of Metcalf, McAdam, Telford, MacNeil, Law, Parnell, and others, and from the parliamentary enactments which placed the problem in the hands of commissioners with a competent engineer backed by large appropriations, made available when the inhabitants of a district, desiring road improvements, would subscribe an equal amount or one-half the estimated cost of the road. In those days there were many warm controversies between the advocates of the several systems, and their good and bad points were frequently explained to special commissions, but the two systems which survived the contest were those of McAdam and Telford. The latter, however, would appear to be based upon the much older plans of the French engineer, Tresaguet, who built many miles of his roads in the latter part of the last century.

A brief description of these systems showing their differences and resemblances would seem to be required. It will be given as nearly as possible in the language of the inventors.

Tresaguet's method, as described by himself in 1764, and as generally adopted in France in 1775, is as follows.¹ See figure 5 :

Fig. 5.



Tresaguet System.

“The bottom of the foundation is to be parallel to the surface of the road. The first bed on the foundation is to be placed on edge and not on the flat in the form of a rough pavement and consolidated by beating with a large hammer, but it is unnecessary that the stones should be even one with another. The second bed is to be equally arranged by hand, layer by layer, and beaten and broken coarsely with a large hammer, so that the stones may wedge together and no empty spaces may remain. The last bed, three

¹ Page 5. “The Maintenance of Macadamized Roads,” by Thomas Codrington, London. E. & F. F. Spoon, London, 1879. New York.

inches in thickness, is to be broken to about the size of a nut, with a small hammer on one side, on a sort of anvil, and thrown upon the road with a shovel to form the curved surface. Great attention must be given to choose the hardest stone for the last bed, even if one is obliged to go to more distant quarries than those which furnish the stone for the body of the road; the solidity of the road depending on this latter bed, one cannot be too scrupulous as to the quality of the materials which are to be used for it."

THE TELFORD ROAD.

In his first report on the great Holyhead Road, May, 1824, Telford describes his method of construction in these words:

"The foundation is a regular close pavement of stones carefully set by hand, and varying in height from eight to six inches, to suit the curvature of the road. The stones are all set on edge, but with the flat one (edge) lowest, so that each shall rest perfectly firm. The interstices are then pinned with small stones; and care is taken that no stone shall be broader than four or five inches, as the upper stratum does not bind upon them so well when they much exceed that breadth. The pavement thus constructed is quite firm and immovable, and forms a complete separation between the top stratum of broken stones and the retentive soil below."

But Telford did not always require a stone pavement for bottoming. In many cases he merely applied whatever material was most available for producing a dry subsoil. He says: "Particular attention should be paid either to find a naturally dry bottom for the roadway or to construct one; and avoid as much as possible the workable materials coming into contact with the clay. And this may always be accomplished by means of gravel, sand, vegetable soil, chalk, or bottoming stone, but this bottoming should be made perfectly firm and regular, so as to receive the top workable metal of equal thickness."

McAdam went so far as to consider a bottoming of large stones not only useless, but injurious. Experience has proven that such a bottom when not wedged in place, but thrown loosely on an undrained soil, will work up to the surface. He preferred a metalling sufficiently thick to form a compact, dry covering impenetrable to rain, and believed that the entire load was carried by the subsoil. This is the chief point of difference between those two systems.

Telford made the bed of the road level in cross section and formed the crowning by making the bottoming stones as well as the metal covering of greater thickness in the center, diminishing towards the sides. But as this required a careful selection of material and made the metal wear more rapidly on the sides, it was not found to be so good in practice as "crowning" the earthy bed of the foundation and making the metallised surface of equal depth throughout.

For a thirty-foot road the side slopes were six inches for the half width, the section being a flat oval or ellipse. When no paved bottoming was used, the convexity was given partly in the gravel bottom, which was seven inches deep in the center and only two at the sides, and partly on the top metalling of broken flint and large gravel, which varied from eight inches in the middle to four at the sides, with one and one-half inches of binding gravel over all this, giving nine inches of convexity in the thirty feet width.

For a section of the Telford road, with pitched bottoming, see Fig. 6.

Fig. 6.



Telford's System.

The difference in cost of construction of these two systems will not differ greatly under the same conditions, since the increased cost of breaking the stones for the McAdam road will be offset by the additional cost of placing and wedging the paved bottoming of Telford's foundation.

What the actual cost of these roads would be must depend upon the accessibility and cost of material and labor in any district, which will be quite variable, but as a guide to an approximate estimate the experience of foreign countries may be taken as a basis.

COST OF STONE ROADS.

In the north of Scotland, on the highlands, where stone is abundant, Telford built 875 miles of road at a cost of £450,000. This total includes several large stone bridges, and gives an

average price of \$2,570 per mile, but it is believed that the actual cost of the roads alone was less than £400 (\$2,000) per mile.

In the Inverness district of Scotland, fourteen and one-fourth miles were built for £4,630, an average of about \$1,500 per mile; again fifteen and one-third miles cost £7,605, or about \$2,500, so that it will be a fair average to place the cost at \$2,000 per mile for these roads where stone is readily available.

The relative cost per lineal yard of Telford and McAdam roads as testified to by Mr. W. A. Provis, assistant engineer to Mr. Telford, is as follows: For a road sixteen feet wide, if stone is to be quarried and carted, say one-fourth of a mile. The section being for the Telford bottoming, seven inches thick at center, five on the sides, with six inches surface covering throughout, the McAdam having a uniform depth of ten inches:

<i>Telford—13 Inches Thick.</i>		<i>McAdam—10 Inches Thick.</i>	
Quarrying $1\frac{3}{4}$ cubic yards measured on the road at 40 cents..	\$0 70	Quarrying and carting 5-6 of the $1\frac{3}{4}$ cubic yards of stone.....	\$0 76
Carting the same at 12 cents....	21	Breaking 10 inches in depth, or $1\frac{1}{2}$ yards at 36.....	54
Setting the bottom	40		
Breaking the top 6 inches 8-9 yards.....	32		\$1 30
	\$1 27		

If there are plenty of loose stones lying around which may be used for the purpose, the relative cost may be reduced to fifty-seven and sixty-one cents respectively per lineal yard. Showing that the first cost does not differ materially, but it is claimed by the advocates of the Telford system that one-third the cost of maintenance is saved by the pitched bottoming. At these several prices the cost per mile for a road sixteen feet wide would be \$2,235.20 for Telford, and \$2,288 for McAdam, where materials have to be quarried, or \$1,003.20 and \$1,073.64 respectively, where loose and suitable stone is abundant. Thus, the price will be found to vary according to the character and distribution of the materials.

A road of the above width will be sufficient for two hay wagons to pass, and will readily accommodate two lines of traffic, but for lines approaching populous cities or connecting important centers the width should be increased up to that for the roadway of city streets, the most economical width of which for a large traffic is four rods.¹ At the same ratio every additional foot of

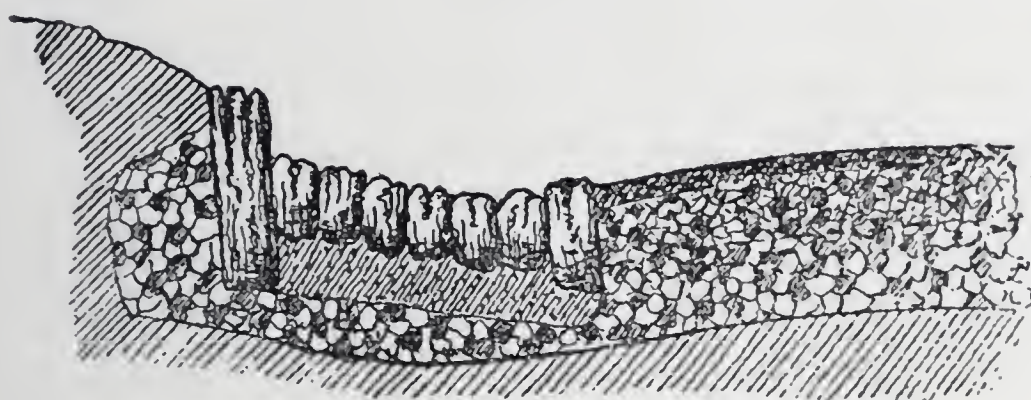
¹ See Best Arrangement of City Streets, Franklin Institute Journal.

width will add one-sixteenth to the cost, hence it is important to determine the amount of traffic, and to make the road sufficiently wide to provide for it, leaving room for future expansion if need be. On all highways there should be, if practicable, space in which to pass or turn around.

THE MCADAM ROAD.

Probably the best idea of this very general method of construction can be given most briefly by a reference to Fig. 7, and a

Fig. 7.



McAdam's System.

few extracts from McAdam's testimony before a parliamentary commission in 1819. In reply to the inquiries of the chairman, he said he had about 180 miles of road under his care in the Bristol District where he then lived, but he had acted as commissioner for various roads for about twenty-five years. He went to England from America in the year 1783, when roads were making in Scotland, and found them very bad there as well as all over the Kingdom. He said: "The defects of the roads appear to proceed principally from the large use of a mixture of clay and chalk and other matters that imbibe water and are affected by frost. * * * I have always found tolls most moderate where the roads are best managed. * * * The best roads are due to the attention paid to the preparation of the materials and to the manner of laying them. * * * I have generally made roads three inches high in the center than at the sides when they are eighteen feet wide; if the road be smooth and well made the water will run off very easily. * * * I should think that ten inches depth of solid materials well consolidated is equal to carry anything whether the substratum was soft or hard; I should rather prefer a soft to a hard one." * * * "In forming a road I never use large stones on

the bottom of the road ; I would not put a large stone in any part of it. The size of the stones should not exceed six ounces in weight. I hold six ounces to be the maximum size. If you make the road of all six-ounce stones it would be a rough road ; but it is impossible but that the greater part of the stones must be under that size.”¹ “The state of disrepair and the amount of expense varies in a pretty exact proportion to the size of the material used.”

* * * “The stone is employed to form a secure, smooth, water-tight flooring.” * * * “Its thickness should be regulated only by the quantity of material necessary to form such a flooring and not by any consideration as to its own independent power of bearing weight.”

Thus it will be seen that McAdam believed the function of the metal was to form an impervious, hard, wearing surface, while the load was carried entirely by the subsoil. He insisted rigidly upon limiting the sizes of the broken stone by weight to six ounces, and required the supervisors to carry scales and test the material constantly. Also, that they should be scrupulously clean and free from dust, and preferred to lay them in three or more layers at different times, and, if possible, in wet or foggy weather.

EARTH ROADS.

Under certain conditions, and with some soils, earth roads are sufficiently good for light traffic, but unfortunately they do not possess the important properties of hardness, smoothness, or permanency ; are readily affected by frost and water, and difficult to keep in even passable condition.

Yet with a knowledge of the most important requirements and careful attention to their fulfilment, earth roads may be greatly improved. These requirements are, first, thorough drainage, and, second, an impervious surface wherever it can be obtained at reasonable expense.

The first may be secured in many places by revising their location so as to take the roads out of the bogs and swamps and put them on gently undulating grounds, where there is sufficient slope to carry off the water, yet not so steep as to produce a wash. Also, by raising the bed a few feet above the general level of the surrounding land, and providing suitable drains at frequent intervals, having grades of not less than 1 in 125. The cross section

¹ Such a stone would be about 1¾ to 1½ inches cube.

should not be "rounded up" from deep ditches on the side as is the custom, but each half should be made nearly flat, having a side slope of about 1 in 20 each way sufficient to carry off the rain, and, if on the road-side of the fences, the side drains should be covered. In regard to the surface, it is not generally known how by combining certain soils in proper proportions an impervious covering can be made. It is commonly recommended to improve an adhesive clay by a surface of six inches of sand, or the reverse, thus neutralizing the prominent characteristics of each, but if the following proportions be observed a good "puddle" material will be produced, which is impervious to water. In preparing puddling for dams and reservoirs it is found that "gravel" with due admixtures of fine materials make the very best embankment to retain water, even under fifty or more feet head.¹

As the voids in gravel constitute about 33 per cent. of the total volume, if a little more than this proportion of sand and clay be mixed with it the pores will be effectually closed.

These proportions are :

Clean common gravel.....	62	per cent.
Sharp sand.....	22½	"
Good clay.....	15½	"
	100	"

Care should be taken, however, in laying a pavement or metalled surface not to place it on a composition of this character, as it would produce a result just the reverse of what is required, having the foundation impervious when it should be porous.

GRAVEL ROADS.

In their natural condition pebbles or gravel having been rounded by attrition are not of a form suitable for binding into a compact, hard, smooth mass for wearing surface ; the chief recommendation of this material is its porosity, which renders it useful for a foundation stratum affording free drainage. An admixture of clay only for the purpose of supplying a binding material or matrix is injurious, as it makes mud and collects water, forming ruts and rapidly destroying the road, thus adding greatly to the cost of maintenance. There are those, however, who advocate the use of a large percentage of the original matrix, found in the gravel pit,

¹ Fanning's Hydraulics.

which, as the road is compacted, should be scraped up and removed. If the gravel is too clean it can never be consolidated, and is continually in motion, causing great wear to the road material, as well as great resistance to traction.

The best practice seems to be to pass the gravel through a screen having three-quarter inch meshes without washing, and using only the larger particles on the road, breaking any that may exceed one and one-half inches into angular fragments. The gravel thus prepared should be spread uniformly over the surface of the road-bed to a depth of not more than six inches, and then either be rolled or thrown open to travel. In any case a sufficient force should be employed to keep the ruts raked down as soon as they appear.

THE RESISTANCES.

These, as have been stated, are due to the yielding nature of the surface, or metalling, the grades and the alignment, as well as the friction of the vehicle, atmosphere, etc.

Without entering into a mathematical discussion of the formula, it will be sufficient to give some of the values of these resistances as determined practically by the dynamometer, from experiments by Sir John MacNeill and M. Morin. The wagon weighed twenty-one hundred weight. To move it at a walk there was required :

On a gravel road laid on earth	147	pounds, or $\frac{1}{16}$ of the load.
On a broken stone road	65	“ $\frac{1}{36}$ “
On a paved foundation	46	“ $\frac{1}{57}$ “
On a well-made pavement	33	“ $\frac{1}{71}$ “
On a stone tramway, per ton	$12\frac{1}{2}$	“ $\frac{1}{179}$ “
On a railroad tramway, per ton	8	“ $\frac{1}{280}$ “

These figures will serve to show how much more effective the power is when applied over a smooth, hard surface.

The following extracts from a comprehensive table will also illustrate this point, and give in addition the relation of grades to length of level roadways.¹

¹ Aide Memoir. Military Science, Vol. III, page 336.

Table of Tractive Force on Different Grades for a Wagon Weighing, with its Load, Six Tons, and Moving at a Velocity of Three Miles per Hour Along a Macadamized Road at its Usual State.

RATE OF INCLINATION IN FEET.	Angle.	Force in pounds to draw up hill.	Force in pounds to draw down.	Equivalent length of level road for ascending. In miles.	Same for the de- scending wagons.
1 in 600.....	0° 5' 44"	286	241	1.085	.9150
1 in 500.....	0 6 53	291	237	1.102	.8979
1 in 400.....	0 8 36	297	230	1.128	.8725
1 in 300.....	0 11 28	309	219	1.170	.8301
1 in 200.....	0 17 11	331	197	1.255	.7451
1 in 100.....	0 34 23	398	129	1.510	.4903
1 in 75.....	0 45 51	443	85	1.680	.3204
1 in 50.....	1 8 6	533	.....	2.019	.....
1 in 40.....	1 25 57	600	.....	2.274	.....
1 in 25.....	1 54 37	712	.....	2.699	.....
1 in 30.....	2 17 26	801	.....	3.038	.....
1 in 20.....	2 51 21	933	.....	3.538	.....
1 in 15.....	3 48 51	1,157	.....	4.388	.....
1 in 12.....	4 45 49	1,379	.....	5.229	.....
1 in 10.	5 42 58	1,600	.....	6.068	.....
1 in 9.....	6 20 25	1,747	.....	6.623	.....
1 in 8.....	7 7 30	1,929	.....	7.315	.....
1 in 7.....	8 7 48	2,162	.....	8.199	.....

From the above it appears that on a grade of one foot in ten it would require six horses to do the work of one, and that the equivalent length of level road would be over six miles. The table tells its own story and shows the great importance of low grades.

“The surface should be brought to a convexity of six inches from the center to the sides by laying on good road materials. The ruts should be filled with hard materials from time to time.

“The space on each side between the sods and the fences should be made smooth with an inclination of one inch in a yard from the road to the fences. Drains should be made along the fences, and all water-courses and drains connected with the road should be constantly kept open and free from weeds.”

